Experimental PMI Facilities in the PFC program

R. Bastasz, 2005 March 17

This is a brief summary of U.S. facilities for the experimental study of plasma-materials interactions (PMI) currently supported by the plasma-facing components (PFC) program.

It is convenient to divide the PMI facilities into three main categories: ion beam experiments, plasma simulator experiments, integrated experiments. Each category has attributes that give experiments in that category similar strengths and weaknesses. *Ion beam experiments* provide the highest level of control of experimental parameters and are best suited for fundamental measurements of PMI. *Plasma simulator experiments* give a high level of control while also providing conditions that can approximate the fusion reactor environment. *Integrated experiments* most closely reproduce the complex conditions experienced by plasma-facing materials in confinement devices, but can be more limited in control or selection of experimental parameters.

Experiments in each of these categories are needed to effectively address PFC program needs. Beam experiments elucidate and characterize PMI processes, plasma simulators study and test materials under a wide variety of conditions, and integrated experiments provide performance data under realistic PMI conditions. Experiments in each category are useful in providing data for testing PMI models.

In a separate category are experiments used to study high-heat flux (HHF) and magneto-hydrodynamic (MHD) effects on materials. Unlike the other PMI experiments, they do not subject materials to energetic ion bombardment. However, they simulate particular effects experienced by materials in the plasma environment and so are included in this compilation.

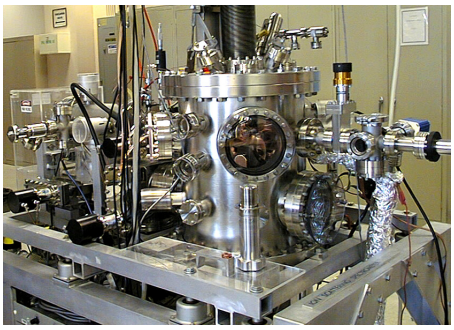
Table I lists the existing experimental facilities by category.

TABLE I: PMI experiments by category

Beam	*Plasma*	*Integrated*	*Other*
ARIES (SNL)	DPE (SNL)	CDX-U* (PPPL)	EB-1200 (SNL/NM)
FLiRE (UIUC)	ESP (UIUC)	DiMES (GA)	EBTS (SNL/NM)
IIAX (UIUC)	PEBL (SNL)	LTX*(PPPL)	LIMITS (SNL/NM)
IMPACT (ANL)	PISCES (USCD)	NSTX (PPPL)	MTOR (UCLA)
	TPE (INL)	*CDX-U to be LTX	

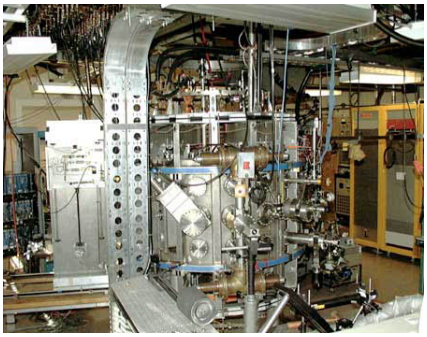
Catalog of PMI experiments for the PFC program

ARIES
Angle-Resolved Ion Energy Spectrometer
Site: SNL/CA
Staff: Bob Bastasz, bastasz@sandia.gov, 925 294–2013
Josh Whaley, jawhale@sandia.gov, 925 294–2677
Link: http://www.ca.sandia.gov/8700/projects/content.php?cid=48



Description: The Angle-Resolved Ion Energy Spectrometer at SNL/CA is an ion beam experiment that provides PMI data on surface composition, sputtering, mixing, segregation effects, and hydrogen isotope recycling on either solid or liquid materials. ARIES obtains PMI data through energy analysis of ions scattered or recoiled from a sample.

CDX–U
Current Drive eXperiment-Upgrade
Site: PPPL
Staff: Bob Kaita, rkaita@pppl.gov, 609 243–3275
Dick Majeski, majeski@pppl.gov, 609 243–3112
Link: http://w3.pppl.gov/~cdx/

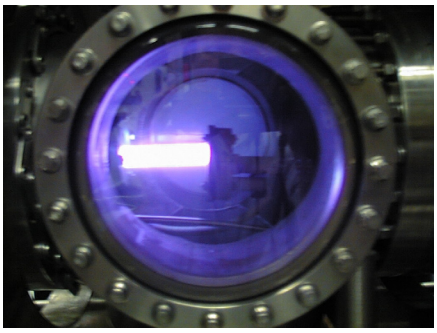


Description: The Current Drive eXperiment-Upgrade at PPPL provides a small-scale plasma facility in which novel ideas can be tested before they are tried on larger devices. It has recently been used to develop liquid Li technology for MFE. CDX-U will soon be converted to LTX.

DiMES
Divertor Materials Evaluation System
Site: GA
Staff: Clement Wong, wongc@fusion.gat.com, 858 455–4258
Dimitry Rudakov, rudakov@fusion.gat.com, 858 455–2895
Link: http://fusion.gat.com/diag/

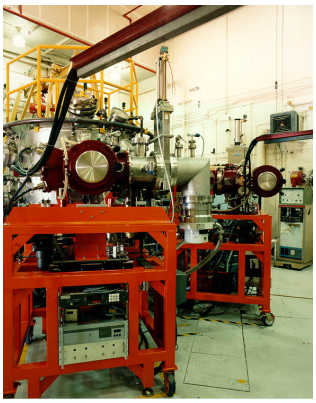
Description: The Divertor Materials Evaluation System is an attachment to the DIII-D tokamak at GA that permits materials and diagnostics to be inserted into the divertor floor during machine operation. It provides integrated PMI testing of both solid and liquid materials.

DPE
Deuterium Plasma Experiment
Site: SNL/CA
Staff: Rion Causey, causey@sandia.gov, 925 294–3326
Josh Whaley, jawhale@sandia.gov, 925 294–2677
Link: http://www.ca.sandia.gov/8700/projects/content.php?cid=47facilitiesframe.html



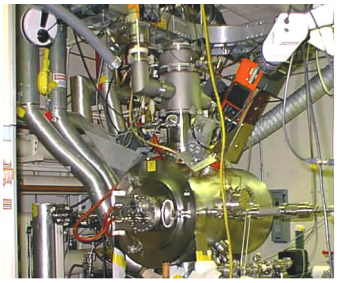
Description: The Deuterium Plasma Experiment is a plasma experiment at SNL/CA used to study retention and release of H and He in solid materials and to simulate redeposition. DPE can irradiate samples of various sizes to a high fluence in the sub-keV ion energy range.

EB-1200
Electron Beam – 1200 kW
Site: SNL/NM
Staff: Dennis Youchison, dlyouch@sandia.gov, 505 845–3138
Link: http://www.sandia.gov/bus-ops/partnerships/



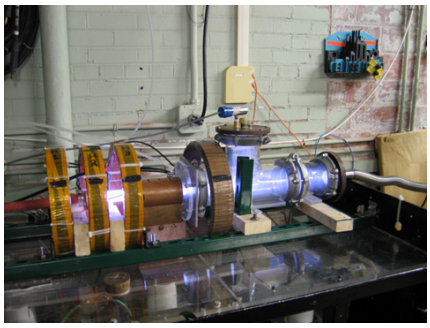
Description: The EB-1200 is a beryllium capable, dual gun, 1.2 MW electron beam HHF facility connected to a high pressure, high temperature water flow loop. It can simulate one-sided plasma heat loads and accommodates medium scale (1 m), actively-cooled PFCs and advanced heat exchangers. It is used to evaluate the thermal response, thermal shock, thermal fatigue and thermalhydraulic performance of armor materials, joints and heatsinks.

EBTS
Electron Beam Test System
Site: SNL/NM
Staff: Dennis Youchison, dlyouch@sandia.gov, 505 845–3138
Link: http://www.sandia.gov/bus-ops/partnerships/tech-access/facilities/pmtf.html



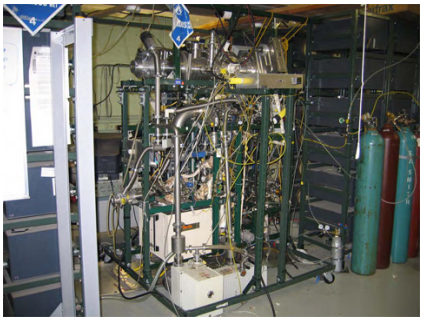
Description: The Electron Beam Test System is a 30 kW electron beam HHF facility used to simulate one-sided plasma heat loads to small scale (10 cm), actively-cooled PFCs and advanced heat exchangers. It is used to evaluate the thermal response, thermal shock, thermal fatigue and thermalhydraulic performance of armor materials, joints and heatsinks. The EBTS is a beryllium capable facility serviced by high temperature, high pressure water, high pressure helium and liquid metal coolant loops.

ESP
ELM Simulating Plasma
Site: UIUC
Staff: David Ruzic, druzic@uiuc.edu, 217 333–0332
Robert Stubbers, stubbers@uiuc.edu 217 333–1750
Link: http://starfire.ne.uiuc.edu/



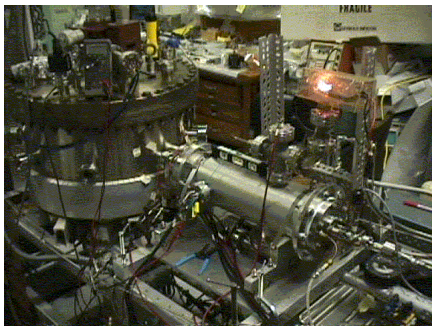
Description: The ELM Simulating Plasma is a plasma experiment at UIUC currently under development. Its purpose is to study erosion and other effects of ELM-like plasma bombardment on PFC materials.

FLiRE
Flowing Lithium Retention Experiment
Site: UIUC
Staff: David Ruzic, druzic@uiuc.edu, 217 333–0332
Robert Stubbers, stubbers@uiuc.edu 217 333–1750
Link: http://starfire.ne.uiuc.edu/flire/



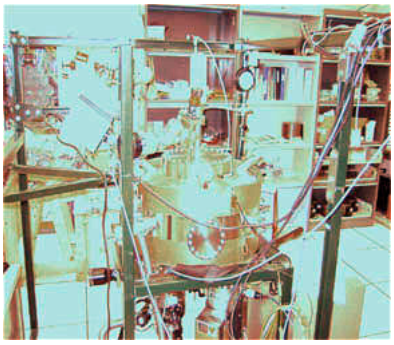
Description: The Flowing Lithium Retention Experiment is an ion beam experiment at UIUC used to primarily to study He retention in flowing liquid metals using a mass spectrometer. It has demonstrated the ability to handle liquid Li.

IIAX
Ion-surface InterActive eXperiment
Site: UIUC
Staff: Matt Coventry, coventry@uiuc.edu, 217 333–8385
David Ruzic, druzic@uiuc.edu, 217 333–0332
Link: http://starfire.ne.uiuc.edu/iiax/iiax.html



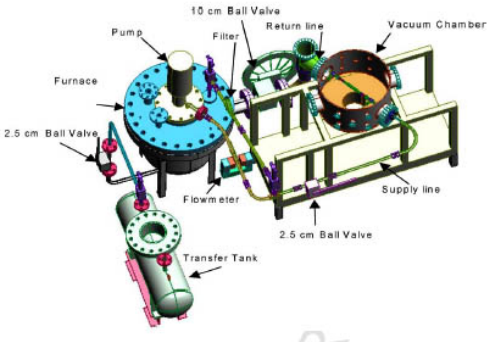
Description: The Ion-surface InterActive eXperiment is an ion beam experiment at UIUC designed to measure the sputtering characteristics of solid and liquid materials. IIAX uses a dual quartz crystal microbalance to precisely measure the quantity of atoms sputtered from a sample, providing fundamental PMI data.

IMPACT
Interaction of Materials with charged-Particles And Components Testing
Site: ANL
Staff: Jean Paul Allain, allain@anl.gov, 630 252–5184
Link: http://www.et.anl.gov/sections/cph/highlights/impact.html



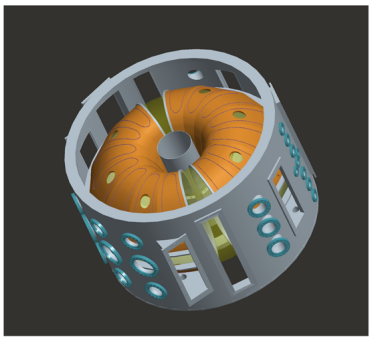
Description: The Interaction of Materials with charged-Particles And Components Testing facility at ANL is a beam experiment being used to study the properties of thin-film Li coatings on various materials. It contains surface analysis components and a quartz microbalance for composition and sputtering measurements.

LIMITS
Liquid Metal Integration Test System
site: SNL/NM
Staff: Tina Tanaka, tjtanak@sandia.gov, 505 844–2981
Link: http://www.sandia.gov/bus-ops/partnerships/tech-access/facilities/pmtf.html



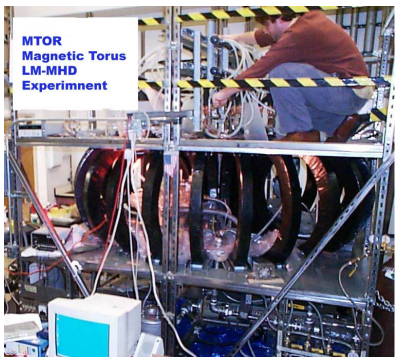
Description: LIMITS is a closed liquid metal loop designed to study MHD effects in flows of molten metals in vacuum under the influence of magnetic field gradients as a preliminary study for flowing liquid surfaces inside of magnetic fusion reactors. When the magnets are removed, the free surface of the flowing liquid can be heated by the EBTS, or the liquid metal can be heated inside a tube or heatpipe assembly.

LTX
Lithium Tokamak eXperiment
Site: PPPL
Staff: Bob Kaita, rkaita@pppl.gov, 609 243–3275
Dick Majeski, majeski@pppl.gov, 609 243–3112
Link: http://w3.pppl.gov/~cdx/



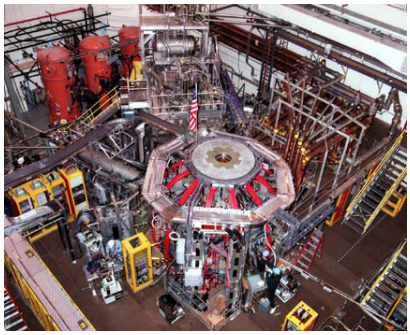
Description: The Lithium Tokamak eXperiment is a modification of the CDX-U device at PPPL designed to test transport and profile modification in plasmas with fully non-recycling walls. In this integrated experiment, the walls will be coated with a thin film of liquid Li prior to initiating a plasma discharge.

MTOR
Magneto-Thermofluid Omnibus Research laboratory
Site: UCLA
Staff: Neil Morley, morley@fusion.ucla.edu, 310 206–1230
Alice Ying, ying@fusion.ucla.edu, 310 206–8815
Link: http://www.fusion.ucla.edu/



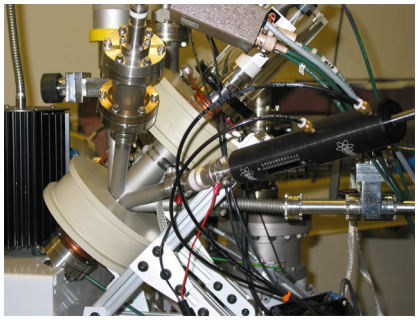
Description: The Magneto-Thermofluid Omnibus Research laboratory at UCLA is a highly flexible collection of high field, high volume magnet systems including a 2T gap magnet and a 24 coil magnetic torus equipped with gallium and lead alloy liquid metal flow loops for studying free surface and closed channel liquid metal MHD and heat transfer phenomena.

NSTX
National Spherical Torus eXperiment
Site: PPPL
Staff: Henry Kugel, hkugel@pppl.gov, 609 243–3146
Rajesh Maingi, rmaingi@pppl.gov, 609 243–3176
Link: http://www.pppl.gov/projects/pages/nstx.html



Description: The National Spherical Torus eXperiment is a major integrated experimental facility at PPPL. It is planned to be used to study boundary and edge-physics effects due to Li pellet injection into the core plasma, Li evaporation onto the walls (ALIST module A) and possibly a flowing Li PFC (ALIST module B).

PEBL
Plasma Entrained Bubbles in Liquids experiment
Site: SNL/CA
Staff: Don Cowgill, dfcowgi@sandia.gov, 925 294–2146
Link: http://www.ca.sandia.gov/8700/projects/
content.php?cid=47



Description: The Plasma Entrained Bubbles in Liquids experiment at SNL/CA is designed to study He retention in liquid metals. It is a plasma experiment that uses a ^{3}He-seeded Penning discharge in conjunction with nuclear reaction analysis (NRA). Retained ^{3}He is dynamically profiled by NRA.

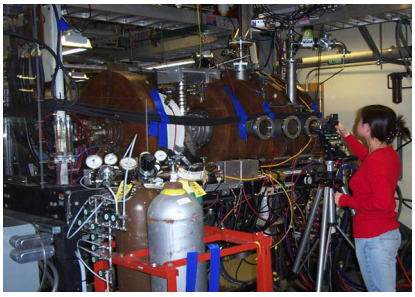
PISCES

Plasma Interaction with Surface and Components Experimental Simulator

Site: UCSD

Staff: Matt Baldwin, mbaldwin@ucsd.edu, 858 822–4117
Russ Doerner, rdoerner@ucsd.edu, 858 534–7830
Stan Luckhardt, sluckhardt@ucsd.edu, 858 534–9725

Link: http://cerfe.ucsd.edu/



Description: The Plasma Interaction with Surface and Components Experimental Simulator is a plasma experiment at UCSD used to study erosion, redeposition, materials mixing, and recycling. Two versions, PISCES-A and PISCES-B, each use a high-flux plasma source and are equipped with both surface and plasma diagnostics. PISCES-B can handle Be samples.

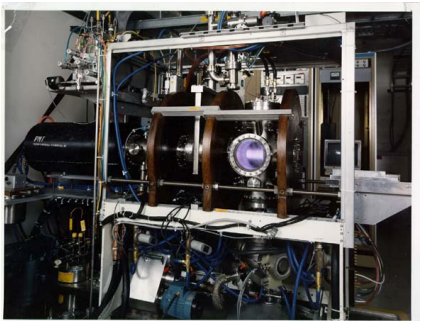
TPE

Tritium Plasma Experiment

Site: INL

Staff: Rion Causey, causey@sandia.gov, 925 294–3326
Phil Sharpe, sharpjp@inel.gov, 208 526–9830

Link: http://www.inel.gov/fusion-safety/



Description: The Tritium Plasma Experiment is a plasma experiment being re-commissioned at INL. It is designed to produce high-flux, tritium-seeded plasmas and can provide data on erosion, recycling, and tritium retention in solid materials.